## PROFESSIONAL ACTIVITIES:

Associate Editor, Bell Journal of Economics, 1974-1983
Associate Editor, Rand Journal of Economics, 1984-1988
Associate Editor, Econometrica, 1978-1987
Reviewer, Mathematical Reviews, 1978-1980
American Editor, Review of Economic Studies, 1979-82
Associate Editor, Journal of Public Economics, 1982-
Associate Editor, Journal of Applied Econometrics, 1985-1993
Member of MIT Center for Energy and Environmental Policy Research, 1973-
Research Associate, National Bureau of Economic Research, 1979-
Member, American Statistical Association Committee on Energy Statistics, 1981-1984
Special Witness (Master) for the Honorable John R. Bartels, U.S. District Court for the Eastern District of New York in Carter vs. Newsday, Inc., 1981-82
Member of Governor's Advisory Council (Massachusetts) for Revenue and Taxation, 1984-1992
Member, Committee on National Statistics, 1985-1990
Member, National Academy of Social Insurance, 1990-
Member, Committee to Revise U.S. Trade Statistics 1990-1992
Director, MIT Telecommunications Economics Research Program, 1988-
Board of Directors, Theseus Institute, France Telecom University, 1988-
Member, Conference on Income and Wealth, National Bureau of Economic Research, 1992-

## PUBLICATIONS:

### I. Econometrics

"Minimum Mean Square Estimators and Robust Regression," Oxford Bulletin of Statistics, April 1974.

"Minimum Distance and Maximum Likelihood Estimation of Structural Models in Econometrics," delivered at the European Econometric Congress, Grenoble: August 1974.

"Full-Information Instrumental Variable Estimation of Simultaneous Equation Models," Annals of Economic and Social Measurment, October 1974.

"Estimation and Inference in Nonlinear Structural Models," Annals of Economic and Social Measurement, with E. Berndt, R.E. Hall, and B.H. Hall, October 1974.

"An Instrumental Variable Approach to Full-Information Estimators in Linear and Certain Nonlinear Econometric Models," Econometrica, May 1975.

"Simultaneous Equations with Errors in Variables," delivered at Winter Econometric Meetings, San Francisco: December 1974; published in Journal of Econometrics 5, 1977, pp. 389-401.

"Social Experimentation, Truncated Distributions, and Efficient Estimation," delivered at the World Econometric Congress, Toronto: August 1975; Econometrica, with D. Wise, June 1977.

"A Conditional Probit Model for Qualitative Choice," delivered at World Econometric Congress, Toronto: August 1975; MIT Working Paper 173, April 1976; Econometrica, with D. Wise, March 1978.

**PUBLICATIONS cont.:**

"Specification Tests in Econometrics," MIT Working Paper 185, June 1976; Econometrica, 1978.

"Non-Random Missing Data," with A.M. Spence, MIT Working Paper 200, May 1977.

"Attrition Bias in Experimental and Panel Data: The Gary Income Maintenance Experiment," with D. Wise, J.F. Kennedy School Working Paper, May 1977; Econometrica, January 1979.

"Missing Data and Self Selection in Large Panels," with Z. Griliches and B.H. Hall, Harvard Economics Department Working Paper, August 1977; delivered at INSEE conference on Panel Data, Paris: August 1977; Annales de l'INSEE, April 1978.

"Stratification on Endogenous Variables and Estimation," with D. Wise, J.F. Kennedy School Working Paper, January 1978; delivered at CME Conference, April 1978; in The Analysis of Discrete Economic Data, ed. C. Manski and D. McFadden, MIT Press, 1981.

"Les models probit de choix qualitatifs," ("Alternative Conditional Probit Specifications for qualitative Choice.") (English Version), September 1977; EPRI report on discrete choice models, presented at INSEE Seminar, Paris: May 1978; Cahiers du Seminar d'Econometrie, 1980.

"The Econometrics of Labor Supply on Convex Budget Sets," Economic Letters, 1979.

"Panel Data and Unobservable Individual Effects," with W. Taylor, MIT Working Paper 225; Econometrica 49, November 1981.

"Comparing Specification Tests and Classical Tests," with W. Taylor, August 1980, Economic Letters, 1981.

"The Effect of Time on Economic Experiments," invited paper at Fifth World Econometrics Conference, August 1980; in Advances in Econometrics, ed. W. Hildebrand, Cambridge University Press, 1982.

"Sample Design Considerations for the Vermont TOD Use Survey," with John Trimble, Journal of Public Use Data, 9, 1981.

"Identification in Simultaneous Equations Systems with Covariance Restrictions: An Instrumental Variable Interpretation," with W. Taylor, December 1980; Econometrica, 1983.

"Stochastic Problems in the Simulation of Labor Supply," presented at NBER conference, January 1981; in Tax Simulation Models, ed. M. Feldstein, University of Chicago Press, 1983.

"The Design and Analysis of Social and Economic Experiments," invited paper for 43rd International Statistical Institute Meeting, 1981; Review of the ISI.

"Specification and Estimation of Simultaneous Equation Models," in Handbook of Econometrics, ed. Z. Griliches and M. Intriligator, vol. 1, 1983.

"Full-Information Estimators," in Kotz-Johnson, Encyclopedia of Statistical Science,vol. 3, 1983

"Instrumental Variable Estimation," in Kotz-Johnson, Encyclopedia of Statistical Science, vol. 4, 1984

**PUBLICATIONS cont.:**

"Specification Tests for the Multinomial Logit Model," with D. McFadden, October 1981; Econometrica, 1984.

"Econometric Models for Count Data with an Application to the Patents R&D Relationship," with Z. Griliches and B. Hall, NBER Working Paper, August 1981; Econometrica, 1984.

"The Econometrics of Nonlinear Budget Sets," Fisher-Shultz lecture for the Econometric Society, Dublin: 1982; Econometrica, 1985.

"The J-Test as a Hausman Specification Test," with H. Pesaran, November 1982; Economic Letters, 1983.

"Seasonal Adjustment with Measurement Error Present," with M. Watson, May 1983; Journal of the American Statistical Association, 1985.

"Efficient Estimation and Identification of Simultaneous Equation Models with Covariance Restrictions," with W. Newey and W. Taylor, October 1983; Econometrica, 1987.

"Technical Problems in Social Experimentation: Cost Versus Ease of Analysis," with D. Wise, in Social Experimentation, ed. J. Hausman and D. Wise, 1985.

"Errors in Variables in Panel Data," with Z. Griliches, Journal of Econometrics, 1986.

"Specifying and Testing Econometric Models for Rank-Ordered Data," with P. Ruud; Journal of Econometrics, 1987.

"Semiparametric Identification and Estimation of Polynomial Errors in Variables Models," with W. Newey, J. Powell and H. Ichimura, 1986, Journal of Econometrics, 1991.

"Flexible Parametric Estimation of Duration and Competing Risk Models," with A. Han, November 1986, revised January 1989, Journal of Applied Econometrics, 1990.

"Consistent Estimation of Nonlinear Errors in Variables Models with Few Measurements," with W. Newey and J. Powell, 1987.

"Nonlinear Errors in Variables: Estimation of Some Engel Curves," Jacob Marschak Lecture of the Econometric Society, Canberra 1988, forthcoming in Journal of Econometrics.

"Optimal Revision and Seasonal Adjustment of Updated Data: Application to Housing Starts," with M. Watson, Journal of the American Statistical Association Proceedings, 1991.

"Seasonal Adjustment of Trade Data," with R. Judson and M. Watson, ed. R. Baldwin, Behind the Numbers: U.S. Trade in the World Economy, 1992.

"Nonparametric Estimation of Exact Consumers Surplus and Deadweight Loss," with W. Newey, 1990, revised 1992, forthcoming Econometrica.

"Misclassification of a Dependent Variable in Qualitative Reponse Models," with F. Scott-Morton, mimeo December 1993.

**PUBLICATIONS cont.:**

## II. Public Finance

"The Evaluation of Results from Truncated Samples," with D. Wise, Annals of Economic and Social Measurement, April 1976.

"Discontinuous Budget Constraints and Estimation: The Demand for Housing," with D. Wise, J.F. Kennedy School Working Paper, July 1977; Review of Economic Studies, 1980.

"The Effect of Taxation on Labor Supply: Evaluating the Gary Negative Income Tax Experiment," with G. Burtless, October 1977; Journal of Political Economy, December 1978.

"AFDC Participation -- Permanent or Transitory?," delivered at NBER-NSF Conference, August 1978; in Papers from the European Econometrics Meetings, ed. E. Charatsis, North Holland: 1981.

"The Effect of Wages, Taxes, and Fixed Costs on Women's Labor Force Participation," March 1979; presented at SSRC-NBER Conference on Taxation, Cambridge, England: June 1979; Journal of Public Economics, October 1980.

"The Effect of Taxes on Labor Supply," presented at Brookings Conference, October 1979; published in How Taxes Affect Economic Behavior, ed. H. Aaron and J. Pechman, Brookings: 1981.

"Income and Payroll Tax Policy and Labor Supply," presented at St. Louis Fed. conference, October 1980; in The Supply Side Effects of Economic Policy, ed. G. Burtless, St. Louis: 1981.

"Individual Retirement Decisions Under an Employer-Provided Pension Plan and Social Security," with G. Burtless, Journal of Public Economics, 1982.

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"Choice Under Uncertainty: The Decision to Apply for Disability Insurance," with J. Halpern, Journal of Public Economics, 1986.

**PUBLICATIONS cont.:**

"Household Behavior and the Tax Reform Act of 1986," with J. Poterba, October 1986; Journal of Economic Perspectives, 1987, also published in French in Annales D'Economie et de Statistique, 1988.

"Involuntary Early Retirement and Consumption," with L. Paquette, ed. G. Burtless, Economics of Health and Aging, 1987.

"Income Taxation and Social Insurance in China," in Sino-U.S. Scholars on Hot Issues in China's Economy, 1990.

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## III. Applied Micro Models

"Project Independence Report: A Review of U.S. Energy Needs up to 1985," Bell Journal of Economics, Autumn 1975.

"Individual Discount Rates and the Purchase and Utilization of Energy Using Durables," MIT Energy Laboratory Working Paper, January 1978; Bell Journal of Economics, Spring 1979.

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"Assessment and Validation of Energy Models," presented at EIA-NBS conference on Energy Models, May 1980; in Validation and Assessment of Energy Models, ed. S. Gass, Washington: Department of Commerce, 1981.

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"Appliance Purchase and Usage Adaptation to a Permanent Time of Day Electricity Rate Schedule," with J. Trimble, August 1983; Journal of Econometrics, 1984.

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"Information Costs, Competition and Collective Ratemaking in the Motor Carrier Industry," presented at Conference On Consensual Decision Making, American University, August 1982; American University Law Review, 1983.

"An Overview of IFFS," presented at EIA-NBS Conference on Energy Models, August 1982; in Intermediate Future Forecasting System, ed. S. Gass et al., Washington: 1983.

"Choice of Conservation Actions in the AHS," November 1982; in Energy Simulation Models, ed. R. Crow, 1983.

"Patents and R&D: Searching for a Lag Structure," with B. Hall and Z. Griliches, in Actes du Colloque Econometrie de la Recherce, Paris: 1983.

"The Demand for Optional Local Measured Telephone Service," in Adjusting to Regulatory, Pricing and Marketing Realities, East Lansing: 1983.

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"Joint Ventures, Strategic Alliances and Collaboration in Telecommunications," presented at International Conference on Joint Ventures in Telecommunications, October 1989, Regulation, 1991.

"An Ordered Probit Model of Intra-day Securities Trading," with A. Lo and C. MacKinlay, Journal of Financial Economics, 1992.

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**PUBLICATIONS cont.:**

"A Utility-Consistent Combined Discrete Choice and Count Data Model: Assessing Recreational Use Losses Due to Natural Resource Damage," with G. Leonard and D. McFadden, October 1992, forthcoming in the Journal of Public Economics.

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"Proliferation of Networks in Telecommunications," presented at Michigan Conference on Regulation, March 1993.

"Valuation of New Goods Under Perfect and Imperfect Competition," mimeo April 1994.

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**JOINT REPORTS, TESTIMONY, AND BOOKS:**

"Project Independence: An Economic Analysis," Technology Review, May 1974.

"The FEA's Project Independence Report: Testimony before Joint Economic Committee," U.S. Congress, March 18, 1975.

"The FEA's Project Independence Report: An Analytical Assessment and Evaluation," NSF Report, June 1975.

"Energy Demand in the ERDA Plan," with D. Wood, Energy Laboratory Report, August 1975.

"A Note on Computational Simplifications and Extensions of the Conditional Probit Model," EPRI report on choice models, September 1977.

"Labor Supply Response of Males to a Negative Income Tax," Testimony for U.S. Senate Finance Subcommittee on Public Assistance, November 22, 1978.

"Appliance Choice with Time of Day Pricing," Energy Laboratory Report, January 1980.

"Discrete Choice Models with Uncertain Attributes," Oak Ridge National Laboratories Report, January 1980.

**JOINT REPORTS, TESTIMONY, AND BOOKS cont.:**

"Individual Savings Behavior," with P. Diamond, Report to the National Commission on Social Security, May 1980.

"Wealth Accumulation and Retirement," with P. Diamond, Report to the Department of Labor, May 1982.
"A Review of IFFS," Report to the Energy Information Agency, February 1982.

"A Model of Heating System and Appliance Choice," with J. Berkovec and J. Rust, December 1983.

"Labor Force Behavior of Older Men After Involuntary Job Loss," with L. Paquette, Report to Department of Health and Human Services, December 1985.

"Pollution and Work Days Lost," with D. Wise and B. Ostrow, NBER Working Paper, January 1984; Revised 1985.

"Demand for Interstate Long Distance Telephone Service," with A. Jafee and T. Tardiff, November 1985.

"Competition in the Information Market 1990", August 1990.

The Choice and Utilization of Energy Using Durables, ed. J. Hausman, Palo Alto: EPRI, 1981.

Social Experimentation, ed. J. Hausman and D. Wise, Chicago: 1985.

Future Competition in Telecommunications, ed. S. Bradley and J. Hausman, Harvard: 1989.

Contingent Valuation: A Critical Appraisal, ed. J. Hausman, North Holland, 1993.

Globalization, Technology and Competition, ed. S. Bradley, J. Hausman, R. Nolan, Harvard 1993.

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Appendix 1

**1994 Price Regression for Top 30 Cellular Markets**
Left hand Side Variable: Log of Price <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 0.539 | 2.052 |
| Log of Income <2 | 0.203 | 0.236 |
| Log of Population <3 | -0.029 | 0.052 |
| Log of Commute Time <4 | 0.624 | 0.266 |
| Regulation | 0.150 | 0.052 |

| | |
|---|---|
| Number of Observations | 58 |
| Standard Error of Regression | 0.148 |
| R Squared | 0.396 |

Notes:
1> Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.
2> Log of per capita personal income. Source: Survey of Current Business, April 1992.
3> Log of population. Source: 1992 Statistical Abstract.
4> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

**1989-93 Price Regression for Top 30 Cellular Markets**
Left hand Side Variable: Log of Price at 160 MOU <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 2.549 | 1.150 |
| Log of Income <2 | 0.075 | 0.143 |
| Log of Population <3 | 0.050 | 0.030 |
| Log of Commute Time <4 | 0.091 | 0.170 |
| Regulation | 0.142 | 0.029 |
| Year 89 | 0.173 | 0.041 |
| Year 90 | 0.127 | 0.036 |
| Year 91 | 0.075 | 0.034 |
| Year 92 | 0.039 | 0.033 |

| | |
|---|---|
| Number of Observations | 198 |
| Standard Error of Regression | 0.152 |
| R Squared | 0.367 |

Notes:
1> Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.
4> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

**1989-93 Price Regression for Top 30 Cellular Markets**
Left hand Side Variable: Log of Price at 250 MOU <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 1.027 | 0.918 |
| Log of Income <2 | 0.256 | 0.114 |
| Log of Population <3 | 0.048 | 0.024 |
| Log of Commute Time <4 | 0.129 | 0.136 |
| Regulation | 0.150 | 0.023 |
| Year 89 | 0.159 | 0.033 |
| Year 90 | 0.122 | 0.029 |
| Year 91 | 0.070 | 0.027 |
| Year 92 | 0.040 | 0.027 |

| | |
|---|---|
| Number of Observations | 198 |
| Standard Error of Regression | 0.121 |
| R Squared | 0.543 |

Notes:
1> Minimum monthly bill is based on 200 minutes of peak calling and 50 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.
4> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

**1989-93 Price Regression for Top 30 Cellular Markets**
Left hand Side Variable: Log of Price at 30 MOU <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 4.701 | 1.752 |
| Log of Income <2 | -0.278 | 0.217 |
| Log of Population <3 | 0.027 | 0.046 |
| Log of Commute Time <4 | 0.257 | 0.259 |
| Regulation | 0.184 | 0.044 |
| Year 89 | 0.102 | 0.062 |
| Year 90 | 0.082 | 0.055 |
| Year 91 | 0.072 | 0.051 |
| Year 92 | 0.063 | 0.051 |

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|---|---|
| Number of Observations | 198 |
| Standard Error of Regression | 0.232 |
| R Squared | 0.165 |

Notes:
1> Minimum monthly bill is based on 24 minutes of peak calling and 6 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.
4> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

**1989-93 Price Regression for RSA Cellular Markets**
Left hand Side Variable: Log of Price at 160 MOU <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 4.341 | 0.411 |
| Log of Income <2 | -0.023 | 0.044 |
| Log of Population <3 | -0.066 | 0.010 |
| Regulation | 0.186 | 0.023 |
| Year 89 | 0.267 | 0.048 |
| Year 90 | 0.289 | 0.024 |
| Year 91 | 0.193 | 0.019 |
| Year 92 | 0.059 | 0.018 |

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|---|---|
| Number of Observations | 577 |
| Standard Error of Regression | 0.169 |
| R Squared | 0.356 |

Notes:
1> Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.

**1989-93 Price Regression for RSA Cellular Markets**
Left hand Side Variable: Log of Price at 250 MOU <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 4.137 | 0.417 |
| Log of Income <2 | 0.025 | 0.045 |
| Log of Population <3 | -0.049 | 0.010 |
| Regulation | 0.159 | 0.024 |
| Year 89 | 0.291 | 0.047 |
| Year 90 | 0.329 | 0.024 |
| Year 91 | 0.191 | 0.019 |
| Year 92 | 0.058 | 0.018 |

| | |
|---|---|
| Number of Observations | 578 |
| Standard Error of Regression | 0.172 |
| R Squared | 0.359 |

Notes:
1> Minimum monthly bill is based on 200 minutes of peak calling and 50 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.

**1989-93 Price Regression for RSA Cellular Markets**
Left hand Side Variable: Log of Price at 30 MOU <1

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 3.524 | 0.530 |
| Log of Income <2 | -0.068 | 0.057 |
| Log of Population <3 | 0.012 | 0.012 |
| Regulation | 0.124 | 0.030 |
| Year 89 | 0.122 | 0.061 |
| Year 90 | 0.256 | 0.031 |
| Year 91 | 0.170 | 0.025 |
| Year 92 | 0.086 | 0.023 |

| | |
|---|---|
| Number of Observations | 577 |
| Standard Error of Regression | 0.218 |
| R Squared | 0.160 |

Notes:
1> Minimum monthly bill is based on 24 minutes of peak calling and 6 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.

**1989-93 Demand Regression for Top 30 Cellular Markets**
Left hand Side Variable: Log of Subscribers

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 0.851 | 2.528 |
| Log of Price <1 | -0.402 | 0.155 |
| Log of Income <2 | 0.188 | 0.309 |
| Log of Population <3 | 0.949 | 0.065 |
| Log of Commute Time <4 | 0.958 | 0.363 |
| Regulation | -0.161 | 0.067 |
| Year 89 | -1.225 | 0.092 |
| Year 90 | -0.807 | 0.080 |
| Year 91 | -0.552 | 0.072 |
| Year 92 | -0.308 | 0.071 |

| | |
|---|---|
| Number of Observations | 196 |
| Standard Error of Regression | 0.322 |
| R Squared | 0.982 |

Notes:
1> Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.
2> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
3> Log of population. Source: NPA Data Services, Inc., April 1994.
4> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

**1989-93 Demand Instrumental Variable Regression for Top 30 Cellular Markets <1**
Left hand Side Variable: Log of Subscribers

| Variable | Estimate | Standard Error |
|---|---|---|
| Intercept | 1.094 | 2.531 |
| Log of Price <2 | -0.500 | 0.172 |
| Log of Income <3 | 0.196 | 0.309 |
| Log of Population <4 | 0.954 | 0.065 |
| Log of Commute Time <5 | 0.965 | 0.363 |
| Regulation | -0.147 | 0.068 |
| Year 89 | -1.209 | 0.093 |
| Year 90 | -0.795 | 0.080 |
| Year 91 | -0.545 | 0.073 |
| Year 92 | -0.304 | 0.071 |

| | |
|---|---|
| Number of Observations | 196 |
| Standard Error of Regression | 0.321 |
| Hausman Specification Test ($\chi^2_1$) | 1.73 |

Notes:
1> Instrumental variables include average price across other Top 30 MSAs, per capita income, population, commute time, and indicator variables for regulation and years.
2> Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.
3> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
4> Log of population. Source: NPA Data Services, Inc., April 1994.
5> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

# THE CELLULAR SERVICE INDUSTRY: PERFORMANCE AND COMPETITION

Prepared for:

THE CELLULAR TELECOMMUNICATIONS INDUSTRY ASSOCIATION

CHARLES RIVER ASSOCIATES

Stanley M. Besen
Robert J. Larner
Jane Murdoch

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## The Performance of the Cellular Industry

From its beginning, the business of supplying cellular telephone communications has been characterized by rapidly increasing volume, declining prices, expanded service offerings, and significant technological change.

The volume of cellular services can be measured either by the number of subscribers or by the minutes of airtime used. The number of cellular telephone subscribers had grown from only 91,600 in January 1985 to an estimated 8.8 million by June 1992. Growth has continued to be rapid, with the number of cellular subscribers increasing by 46 percent during the 12 months ending June 1991 and by 39 percent in the 12 months ending June 1992.[1] The number of cellular subscribers is projected to be 19 million by 1995 and 38 million by 2001.[2] Growth in cellular airtime also has been substantial, although it has been slower than the growth in the number of subscribers because later subscribers have tended to use the service less intensively than earlier adopters. This change reflects the increased importance of residential users of cellular telephones relative to business users.

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[1]Cellular Telecommunications Industry Association, Industry Data Survey, June 30, 1992, p. 1. The growth in volume that has occurred has far exceeded expectations. When commercial cellular service began in the United States in 1983, the potential demand in the year 2000 was thought to be between one and two million subscribers; see Coopers & Lybrand, Technological Change and the Cellular Telecommunications Industry (November 1991), p. 15.

[2]Linden Corporation, Cellular Network Technology, End User Requirements, and Competition to the Year 2001, 1991, p. 244.

Contributing to this increasing volume has been a steady decline in the costs of owning and using cellular telephones. For example, the nominal price for 250 minutes of prime airtime usage per month across the ten largest cellular service areas had, in 1989, declined by 19 percent from the inception of commercial cellular service in 1983. Even with a slight increase in carrier charges estimated for 1991 and 1992, the unweighted average of the lowest published rate for access and 250 minutes of usage during prime time in these ten service areas was only 85 percent of its 1983 level. When adjusted for inflation, the average of these rates in the ten largest cellular service areas in 1991 was only 62 percent of its 1983 level.[3]

The monthly cost of a mobile cellular telephone has declined by even more than carrier charges, from $79 in 1983 to $7 in 1991. During the same time, the quality of mobile telephone service was also enhanced by improvements in functions and features. When adjusted for inflation, the total cost of owning and using a cellular telephone in 1991 was only 44 percent of its cost in 1983.[4]

Cellular subscribers have benefitted not only from falling prices but also from the continually expanding variety of services offered by cellular operators. Only five years ago, there were no

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[3]Data are from Herschel Shosteck Associates, Ltd., Cellular Market Forecasts, Data Flash, September 1992.

[4]Data are from Shosteck, op. cit., and measure the "drive away" price of a single mobile telephone, including antenna, installation, and first-year maintenance.

value-added cellular services. Today, cellular providers offer a number of information services as well as features such as voice mail, call forwarding, and call waiting. There have been major advances in data transmission as well, including portable facsimile and wireless transmission for laptop computers. New services continue to be developed. For example, cellular telephones now are being used to verify credit cards and to transmit information to and from remote locations in computerized monitoring and reporting systems.

Technological advances in recent years also have enabled cellular systems to expand their capacity. Several capacity-increasing innovations have occurred in the conventional or analog cellular technology, such as adjusted power output, antenna tilting, dynamic channel assignment, and cell repeaters and umbrella (underlay/overlay).[5]

Notwithstanding the continuing improvements in analog-based cellular systems, even more dramatic advances are expected from the further development and application of digital technology. Virtually all cellular switches made today are digital, and the shift to this technology is expected to occur in base station radios and subscriber telephones during the 1990s.[6]

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[5]H. Shosteck, "The question marks over PCNs," Mobile Europe, January 1991, no pagination.

[6]Coopers & Lybrand, op. cit., pp. 59-60. During a transition period, cellular phones will be dual mode, adaptable to both digital and analog systems.

The conversion to digital technology, despite the substantial investment required, promises to yield even greater increases in system capacity and lower average costs for cellular operators. For example, the capacity of base stations will at least triple initially. In addition, digital technology will permit new services to be provided.[7]

Competition in the Supply of Cellular Services

This performance of the cellular service industry is the kind that economists associate with a young industry driven by market forces and developing in a competitive context,[8] and it has occurred without the industry's having a competitive structure, as economists define that term.[9] The FCC has determined that the cellular service business should be a structural duopoly: only two facilities-based suppliers, one wireline carrier and one nonwireline carrier, are permitted to operate in a service area, with additional facilities-based entry barred. Economists have recognized, however, that the behavior of firms and the performance of an industry can approximate the competitive outcome even if the

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[7] Ibid., p. 60.

[8] While this record of performance is consistent with a competitive industry, it does not prove that the industry is necessarily competitive, since even a monopolist facing conditions of increasing demand and reduced costs is likely to earn greater profits by lowering price, expanding output, and making innovations in products and methods of production.

[9] Economists call a market structure competitive when entry is easy, firms are numerous, and no firm has a large market share. As we point out in the text, the performance of a market can be competitive even if its structure is not.

industry does not consist of a large number of firms, none of which serves a large share of the market.

Economists consider the number and size distribution of firms in a market to be important initial indicators of the likelihood of noncompetitive behavior.[10] Collusive arrangements, whether explicit or tacit, are more likely when there are only a few firms, simply because coordination is easier. Similarly, the costs of monitoring the behavior of others and enforcing any collusive arrangement by punishing "cheaters" are lower when there are few industry participants.[11] The size distribution of firms also affects the ease of coordination. A small number of very large firms may serve as coordinators in an industry that also includes many small firms.

However, economists also recognize that the competitive outcome, where prices are driven to marginal costs, may obtain even in industries with as few as two firms.[12] Theoretical models of the strategic interactions between duopolists predict a broad range of outcomes, from monopolistic to perfectly competitive.[13] In

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[10]M. Spence, "Tacit Co-ordination and Imperfect Information," Canadian Journal of Economics XI (1978), pp. 497 and 499.

[11]J.S. Bain, "Relation of Profit Rate to Industry Concentration," Quarterly Journal of Economics LXV (1951), pp. 205-206.

[12]The best-known model demonstrating this result is found in J. Bertrand, "Théorie Mathématique de la Richesse Sociale," Journal des Savants, 1883, pp. 499-508.

[13]A large body of economic literature, predicting a range of competitive outcomes, is reviewed in J. Tirole, The Theory of Industrial Organization (Cambridge, MA: The MIT Press, 1988), pp. 225-308.

these models, firms choose whether to cooperate and at which price. The outcome depends on the reaction that each firm expects from its competitor to changes in its own price or output. This, in turn, determines the gains that each firm expects from undercutting a noncompetitive price, and the expected cost of being punished if such deviation is detected. Even duopolists do not necessarily react to each other's actions in ways that maximize joint profits: a duopoly is not the same as a monopoly.

The decision rules that comprise a firm's competitive strategy are difficult to infer from its observed behavior. Nonetheless, economists have identified a number of significant factors, in addition to the number of its rivals, that influence the strategies each firm pursues, and thus help to determine how close to the competitive outcome the industry's performance will be.[14] These are factors that make collusive practices more or less difficult to establish, and affect the ease with which deviations from a collusive outcome can be detected and punished. Several of these factors are likely to influence the performance of the cellular service industry, albeit to varying degrees.

One of the most striking features of the mobile communication industry is the rapid pace of technological innovation and diffusion. Transmission technology has evolved from analog to digital, and cellular telephones have become truly portable, shrinking to pocket size. The rate of technological change and the

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[14]G. J. Stigler, "A Theory of Oligopoly," Journal of Political Economy 74 (1964), pp. 44-61.

resulting speed with which the customer base is growing are two influences that economists consider procompetitive.

The rapid technological change in the provision of cellular service imparts a high degree of variability to the services offered and the prices of those services. In these circumstances, a collusive agreement is difficult to maintain, because the price of each new service must be integrated into the existing price structure.[15] As providers adopt new technologies, the introduction of new service packages offers opportunities to "cheat" on a noncompetitive agreement without provoking the "punishment" that might otherwise occur, because it is difficult for a rival to determine what the appropriate price of the new service should be. If new services are offered at more competitive prices, because it is easier to deviate from a collusive agreement when products are changing, or even if rivals only perceive that the new services are being offered at prices that are "too low" because they do not know what those prices should be, a collusive agreement may be difficult to establish and maintain.

The rapid rate of technological innovation not only hinders the smooth functioning of a collusive pricing agreement but, by leading to rapid market growth, also may weaken the incentive for firms to participate in such agreements. When markets are growing

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[15]R.A. Posner, Antitrust Law: An Economic Perspective (Chicago, IL: The University of Chicago Press, 1976), pp. 59-60.